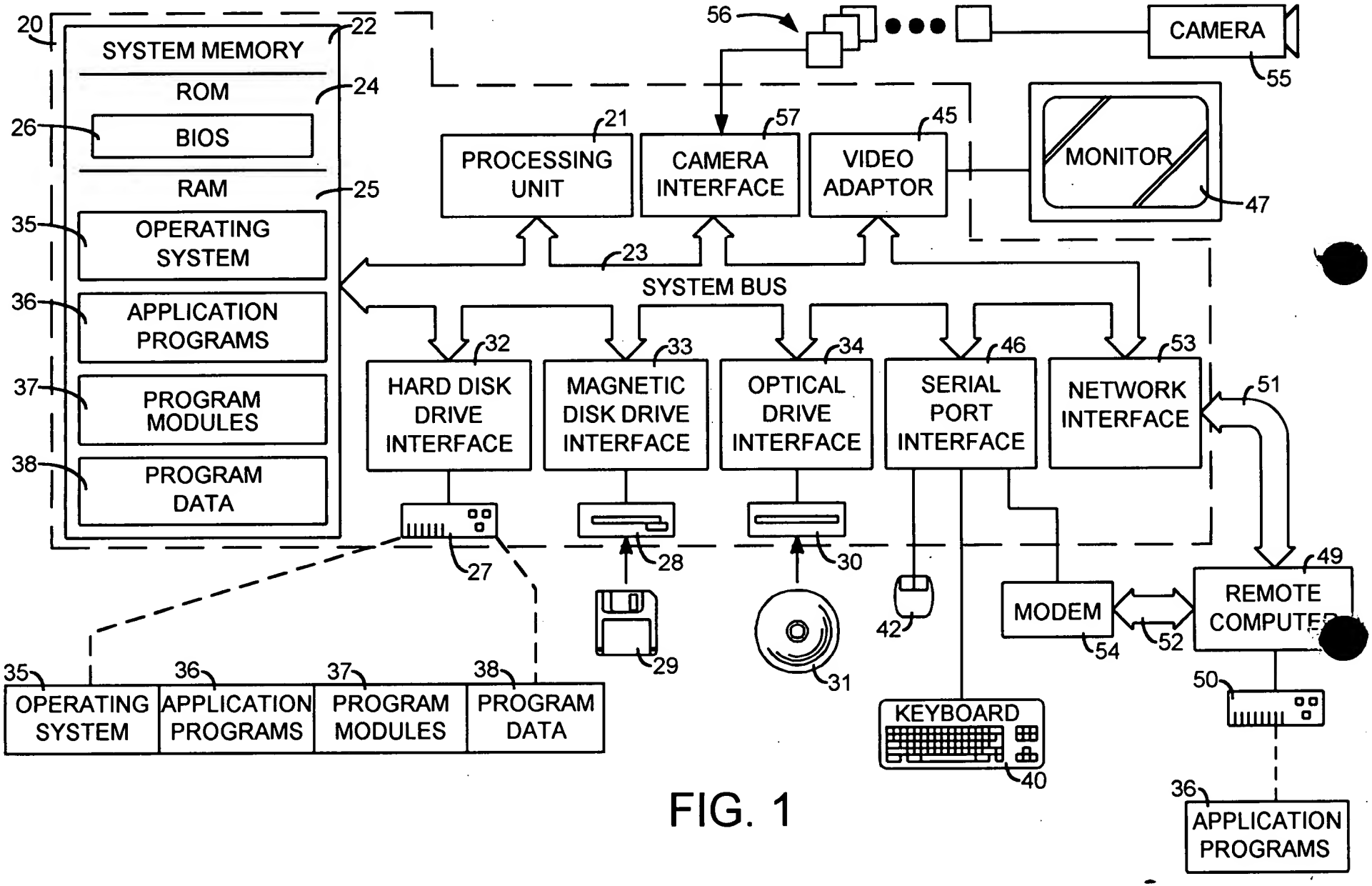

20
SYSTEM MEMORY
22
ROM
24
26
BIOS
RAM
25
35
OPERATING SYSTEM
36
APPLICATION PROGRAMS
37
PROGRAM MODULES
38
PROGRAM DATA
56
CAMERA
55
21
PROCESSING UNIT
57
CAMERA INTERFACE
45
VIDEO ADAPTOR
MONITOR
47
23
SYSTEM BUS
32
HARD DISK DRIVE INTERFACE
33
MAGNETIC DISK DRIVE INTERFACE
34
OPTICAL DRIVE INTERFACE
46
SERIAL PORT INTERFACE
53
NETWORK INTERFACE
51
27
28
30
29
31
42
MODEM
54
52
REMOTE COMPUTER
49
50
KEYBOARD
40
36
APPLICATION PROGRAMS
35
OPERATING SYSTEM
36
APPLICATION PROGRAMS
37
PROGRAM MODULES
38
PROGRAM DATA

FIG. 1

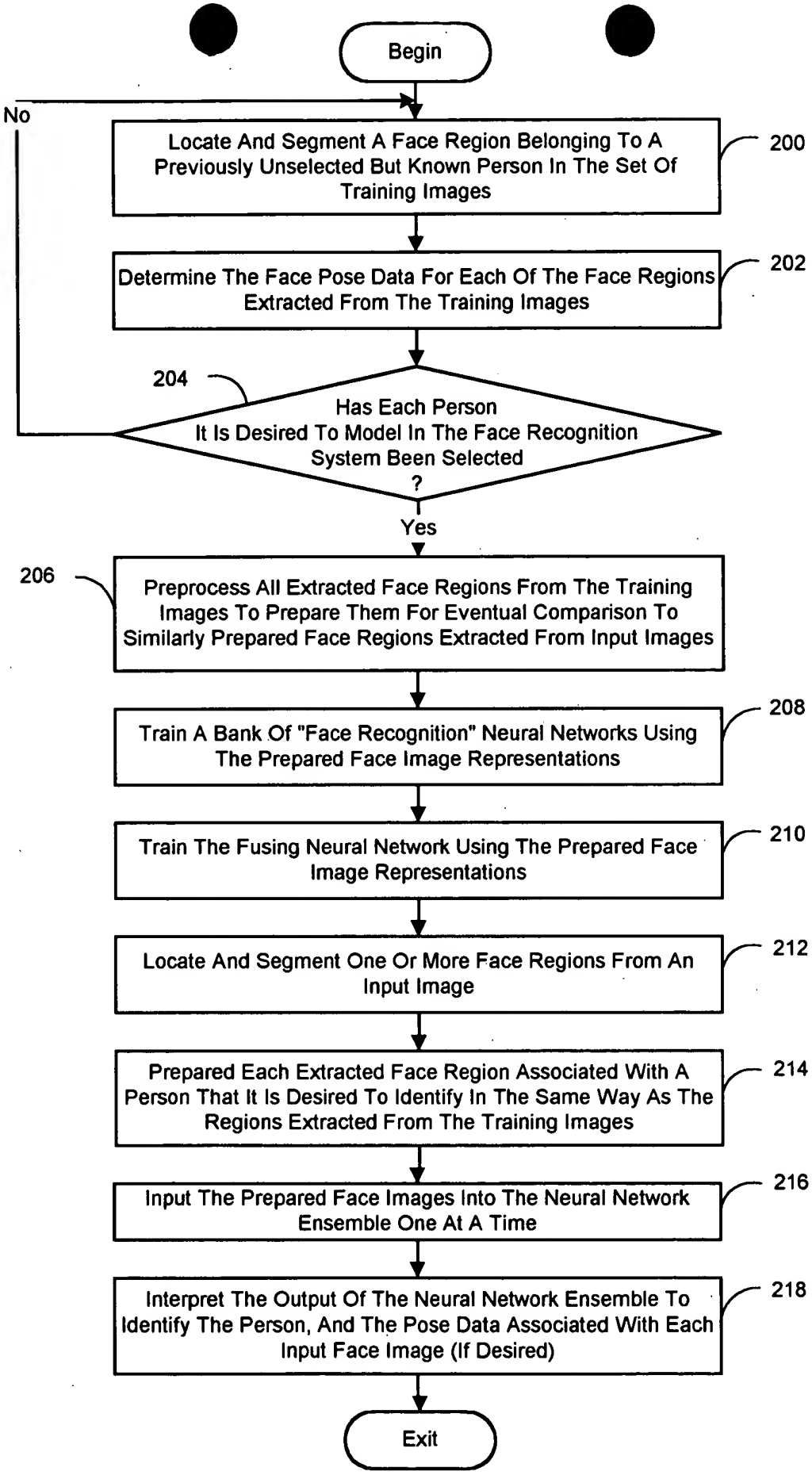

Begin
No
Locate And Segment A Face Region Belonging To A Previously Unselected But Known Person In The Set Of Training Images
200
Determine The Face Pose Data For Each Of The Face Regions Extracted From The Training Images
202
204
Has Each Person It Is Desired To Model In The Face Recognition System Been Selected ?
Yes
206
Preprocess All Extracted Face Regions From The Training Images To Prepare Them For Eventual Comparison To Similarly Prepared Face Regions Extracted From Input Images
Train A Bank Of "Face Recognition" Neural Networks Using The Prepared Face Image Representations
208
Train The Fusing Neural Network Using The Prepared Face Image Representations
210
Locate And Segment One Or More Face Regions From An Input Image
212
Prepared Each Extracted Face Region Associated With A Person That It Is Desired To Identify In The Same Way As The Regions Extracted From The Training Images
214
Input The Prepared Face Images Into The Neural Network Ensemble One At A Time
216
Interpret The Output Of The Neural Network Ensemble To Identify The Person, And The Pose Data Associated With Each Input Face Image (If Desired)
218
Exit

FIG. 2

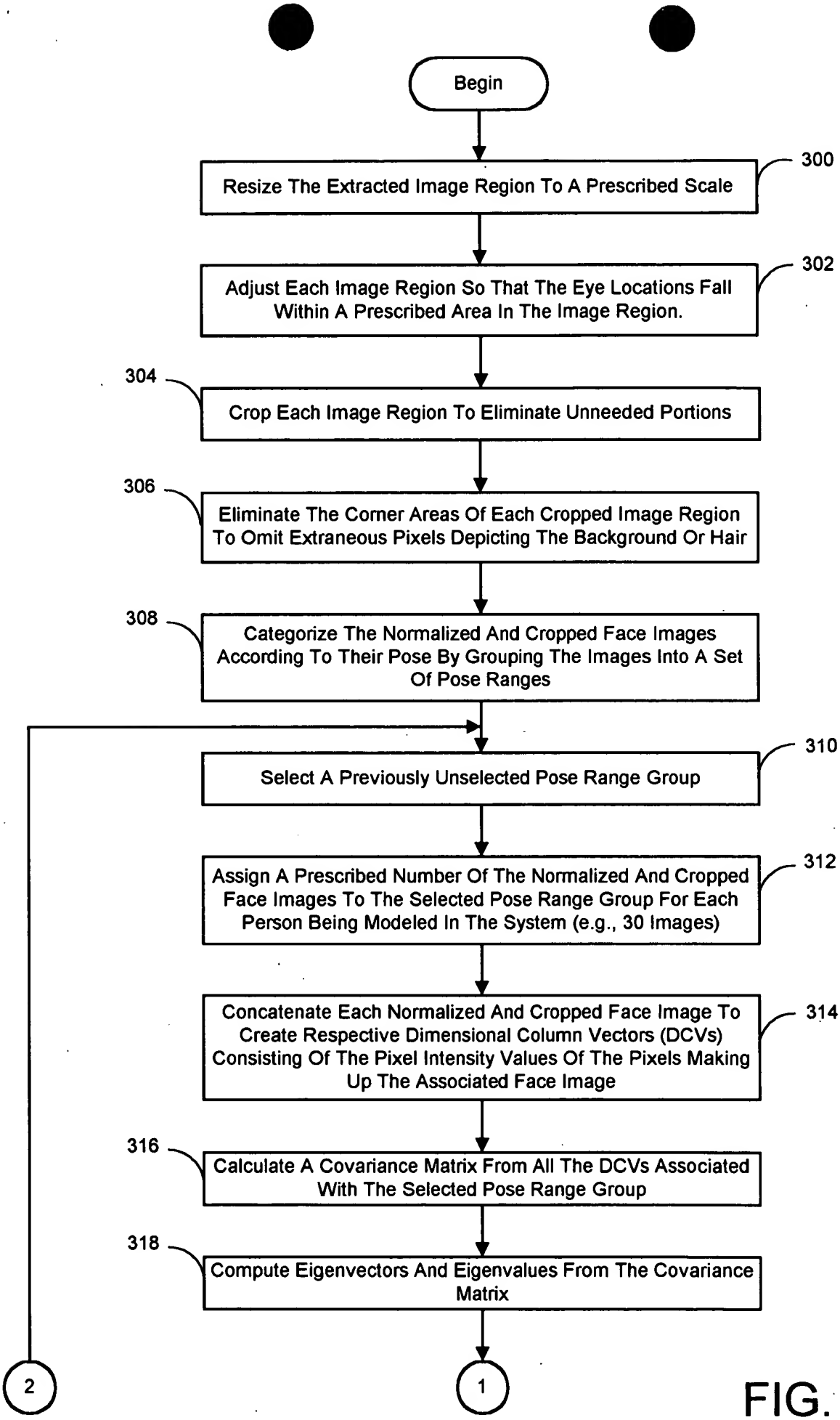

Begin
Resize The Extracted Image Region To A Prescribed Scale
300
Adjust Each Image Region So That The Eye Locations Fall Within A Prescribed Area In The Image Region.
302
304
Crop Each Image Region To Eliminate Unneeded Portions
306
Eliminate The Corner Areas Of Each Cropped Image Region To Omit Extraneous Pixels Depicting The Background Or Hair
308
Categorize The Normalized And Cropped Face Images According To Their Pose By Grouping The Images Into A Set Of Pose Ranges
310
Select A Previously Unselected Pose Range Group
312
Assign A Prescribed Number Of The Normalized And Cropped Face Images To The Selected Pose Range Group For Each Person Being Modeled In The System (e.g., 30 Images)
314
Concatenate Each Normalized And Cropped Face Image To Create Respective Dimensional Column Vectors (DCVs) Consisting Of The Pixel Intensity Values Of The Pixels Making Up The Associated Face Image
316
Calculate A Covariance Matrix From All The DCVs Associated With The Selected Pose Range Group
318
Compute Eigenvectors And Eigenvalues From The Covariance Matrix
2
1

FIG. 3A

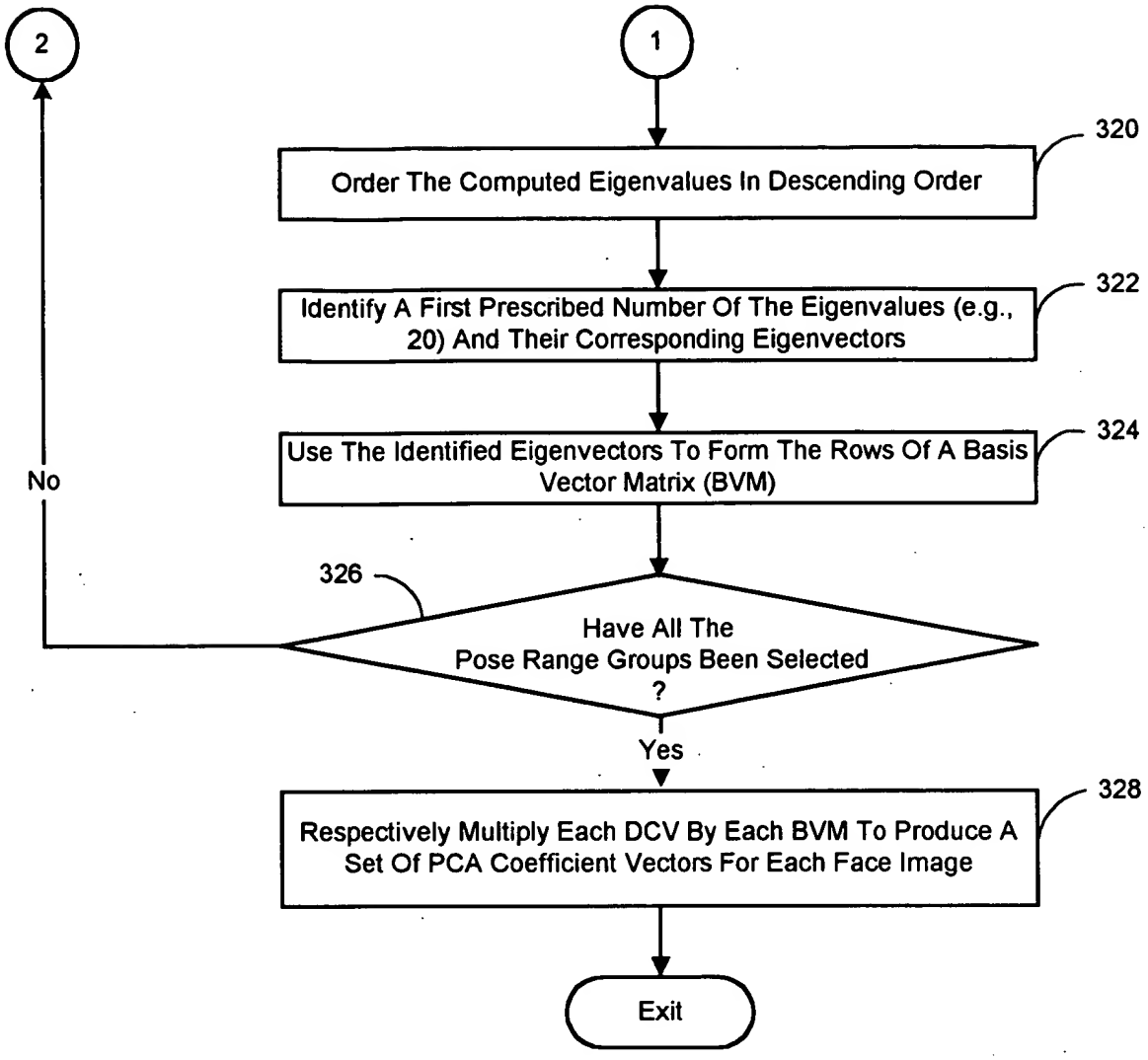

2
1
Order The Computed Eigenvalues In Descending Order
320
Identify A First Prescribed Number Of The Eigenvalues (e.g., 20) And Their Corresponding Eigenvectors
322
Use The Identified Eigenvectors To Form The Rows Of A Basis Vector Matrix (BVM)
324
326
Have All The Pose Range Groups Been Selected ?
No
Yes
Respectively Multiply Each DCV By Each BVM To Produce A Set Of PCA Coefficient Vectors For Each Face Image
328
Exit

FIG. 3B

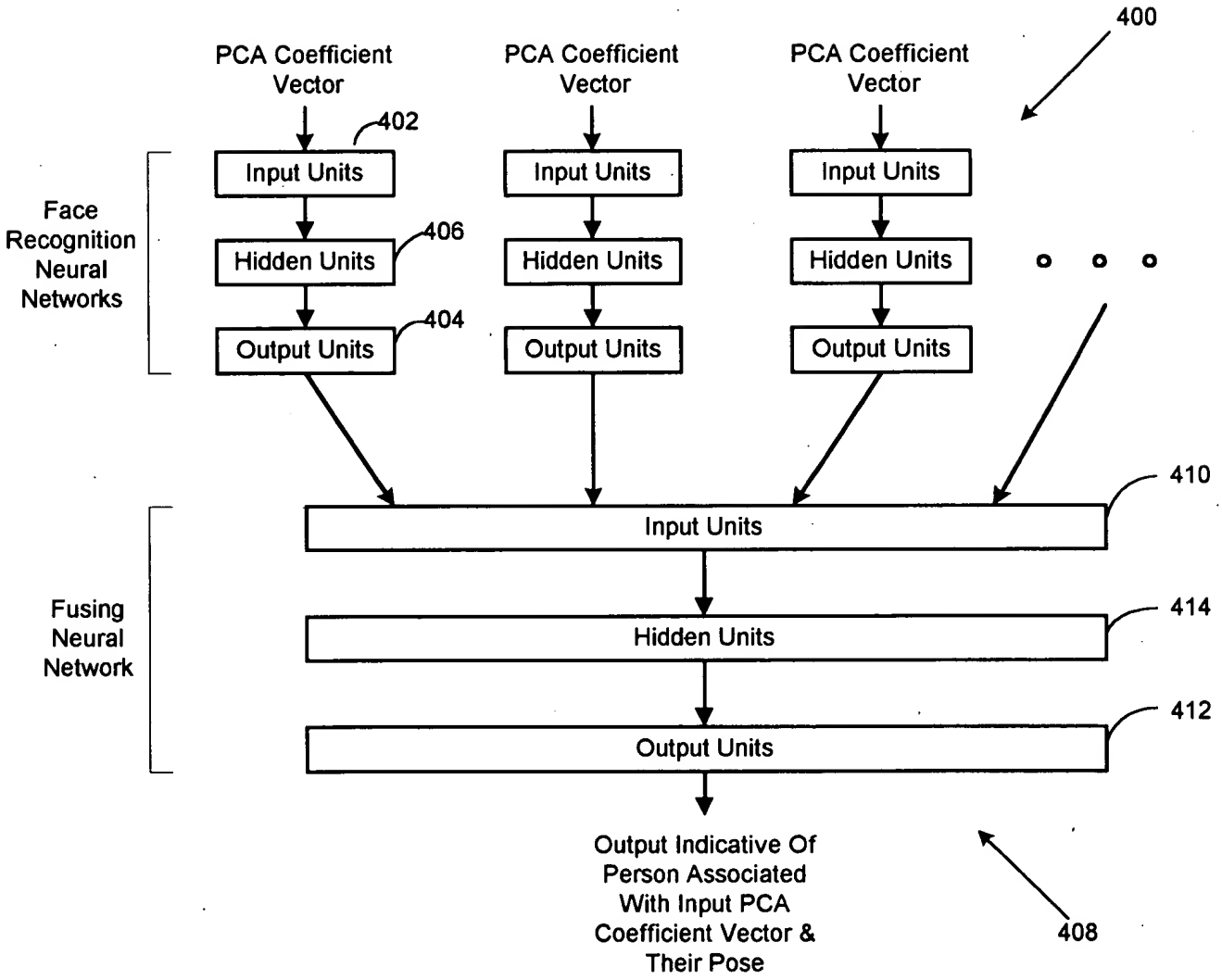

400
PCA Coefficient Vector
PCA Coefficient Vector
PCA Coefficient Vector
402
Input Units
Input Units
Input Units
Face Recognition Neural Networks
406
Hidden Units
Hidden Units
Hidden Units
404
Output Units
Output Units
Output Units
410
Input Units
Fusing Neural Network
414
Hidden Units
412
Output Units
Output Indicative Of Person Associated With Input PCA Coefficient Vector & Their Pose
408

FIG. 4

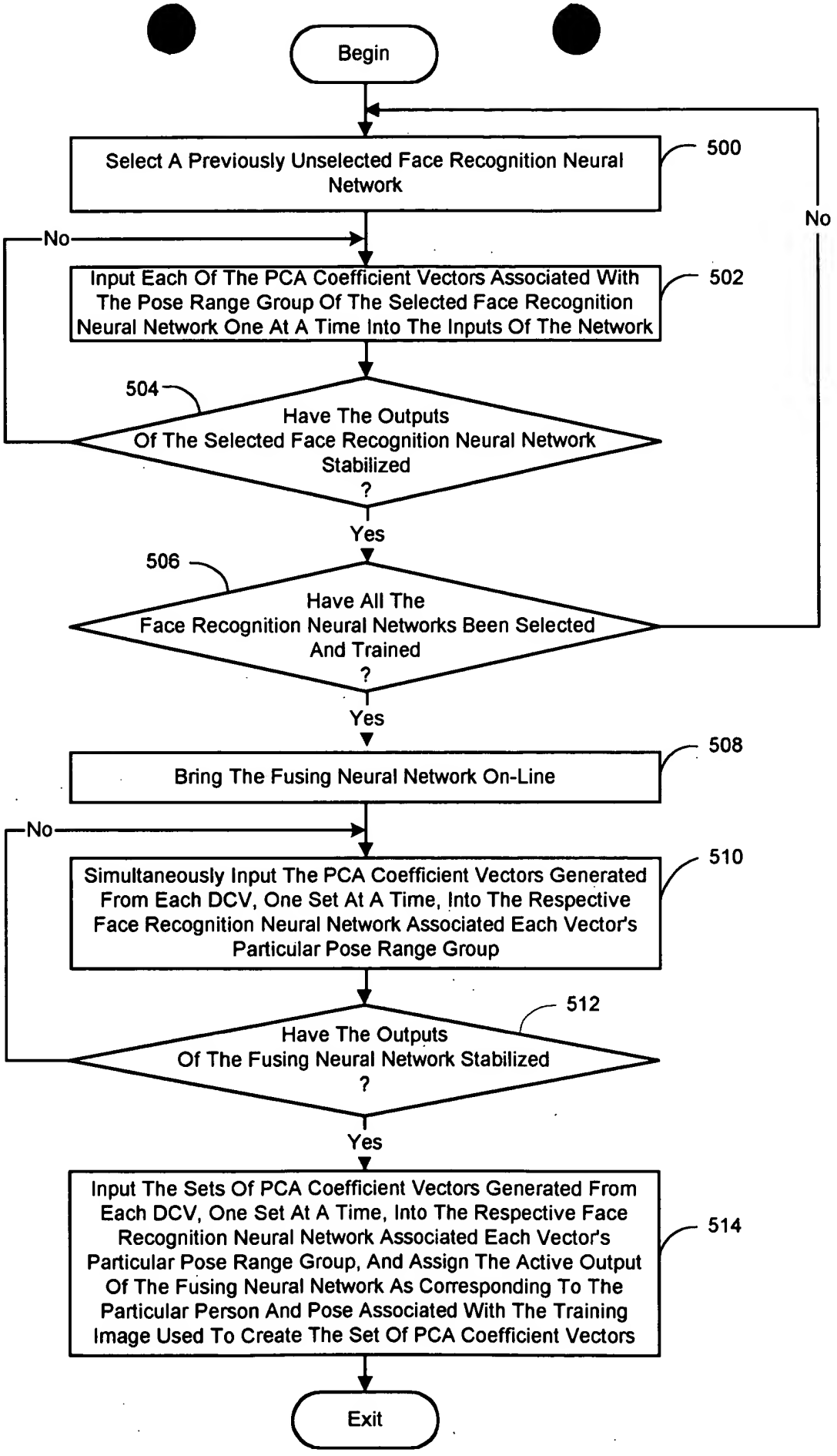

Begin
Select A Previously Unselected Face Recognition Neural Network
500
No
Input Each Of The PCA Coefficient Vectors Associated With The Pose Range Group Of The Selected Face Recognition Neural Network One At A Time Into The Inputs Of The Network
502
504
Have The Outputs Of The Selected Face Recognition Neural Network Stabilized ?
No
Yes
506
Have All The Face Recognition Neural Networks Been Selected And Trained ?
No
Yes
Bring The Fusing Neural Network On-Line
508
No
Simultaneously Input The PCA Coefficient Vectors Generated From Each DCV, One Set At A Time, Into The Respective Face Recognition Neural Network Associated Each Vector's Particular Pose Range Group
510
512
Have The Outputs Of The Fusing Neural Network Stabilized ?
Yes
Input The Sets Of PCA Coefficient Vectors Generated From Each DCV, One Set At A Time, Into The Respective Face Recognition Neural Network Associated Each Vector's Particular Pose Range Group, And Assign The Active Output Of The Fusing Neural Network As Corresponding To The Particular Person And Pose Associated With The Training Image Used To Create The Set Of PCA Coefficient Vectors
514
Exit

FIG. 5

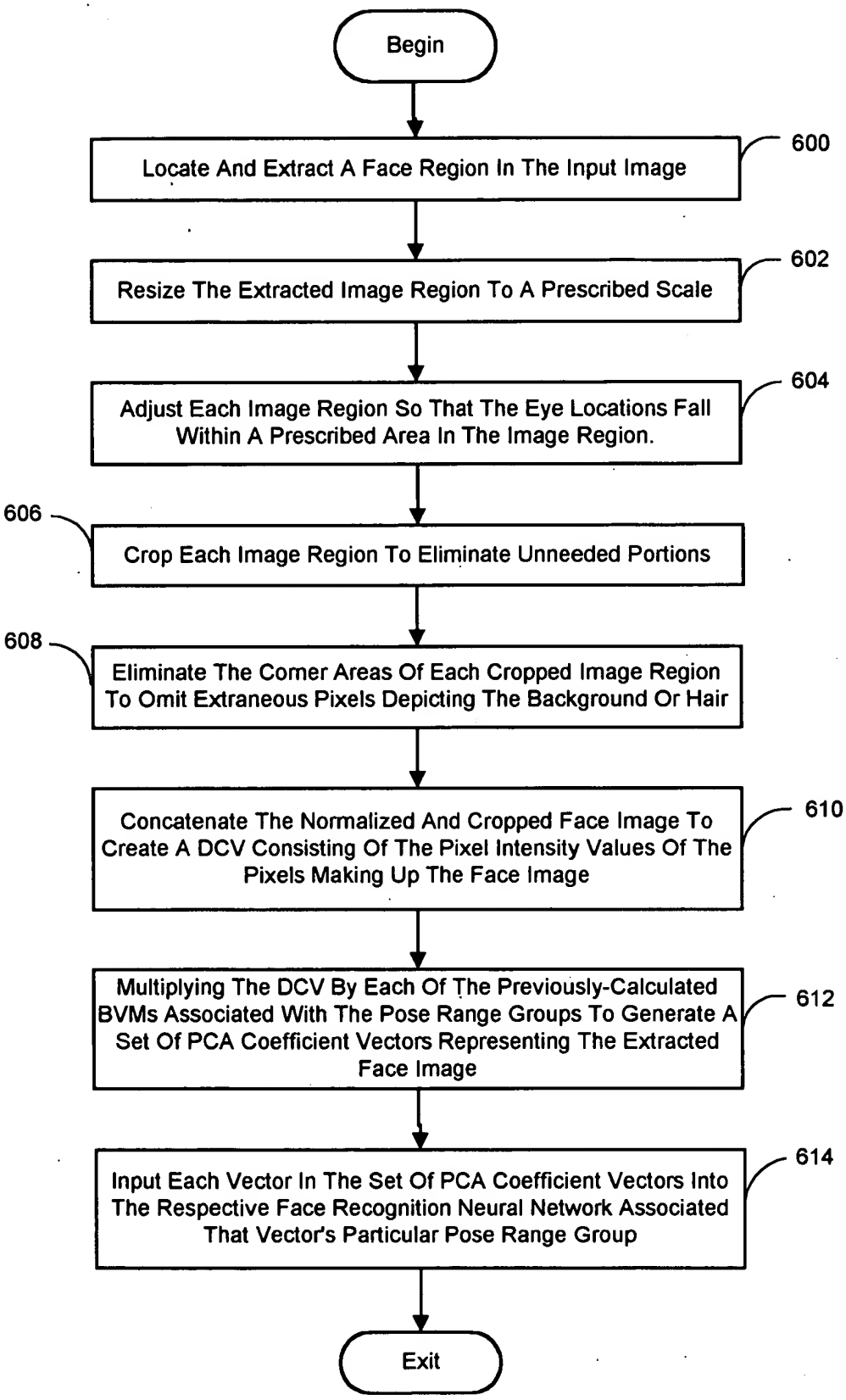

Begin
Locate And Extract A Face Region In The Input Image
600
Resize The Extracted Image Region To A Prescribed Scale
602
Adjust Each Image Region So That The Eye Locations Fall Within A Prescribed Area In The Image Region.
604
606
Crop Each Image Region To Eliminate Unneeded Portions
608
Eliminate The Corner Areas Of Each Cropped Image Region To Omit Extraneous Pixels Depicting The Background Or Hair
Concatenate The Normalized And Cropped Face Image To Create A DCV Consisting Of The Pixel Intensity Values Of The Pixels Making Up The Face Image
610
Multiplying The DCV By Each Of The Previously-Calculated BVMs Associated With The Pose Range Groups To Generate A Set Of PCA Coefficient Vectors Representing The Extracted Face Image
612
Input Each Vector In The Set Of PCA Coefficient Vectors Into The Respective Face Recognition Neural Network Associated That Vector's Particular Pose Range Group
614
Exit

FIG. 6

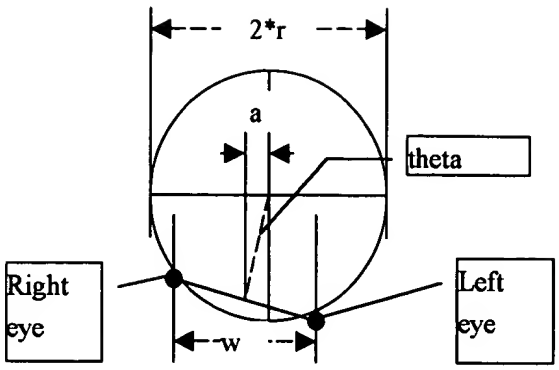



FIG. 7

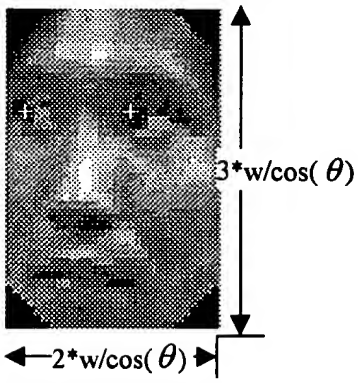



FIG. 8

FIG. 9

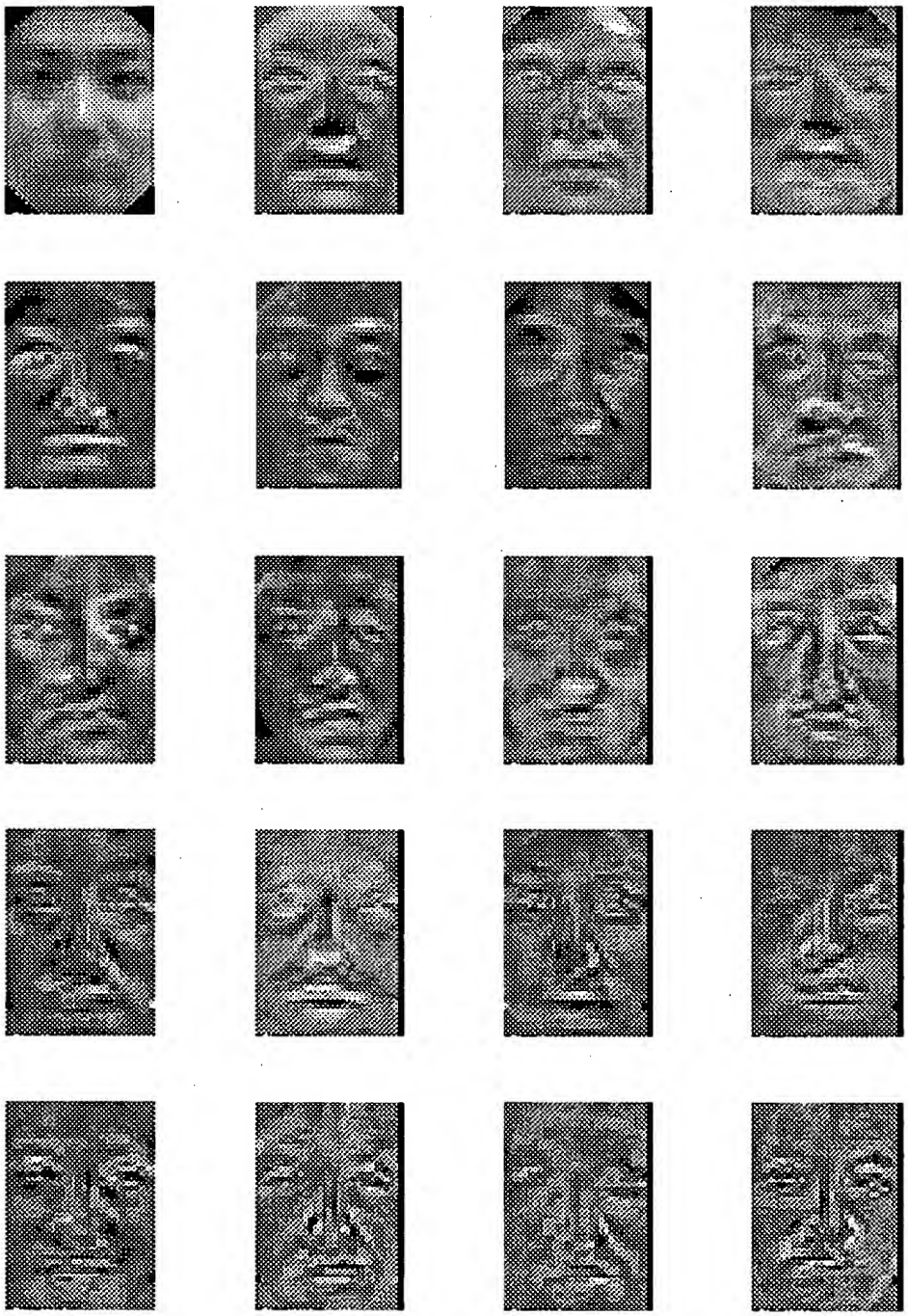


FIG. 10

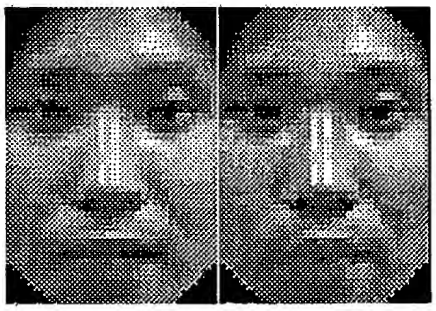
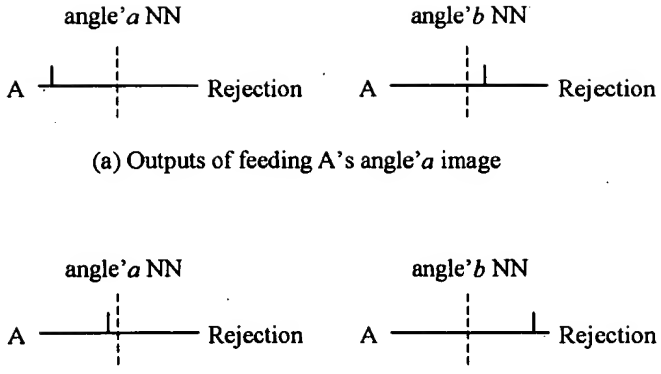


FIG. 11




(a) Outputs of feeding A's angle'*a* image




(b) Outputs of feeding Rejection's angle'*b* image

FIG. 13

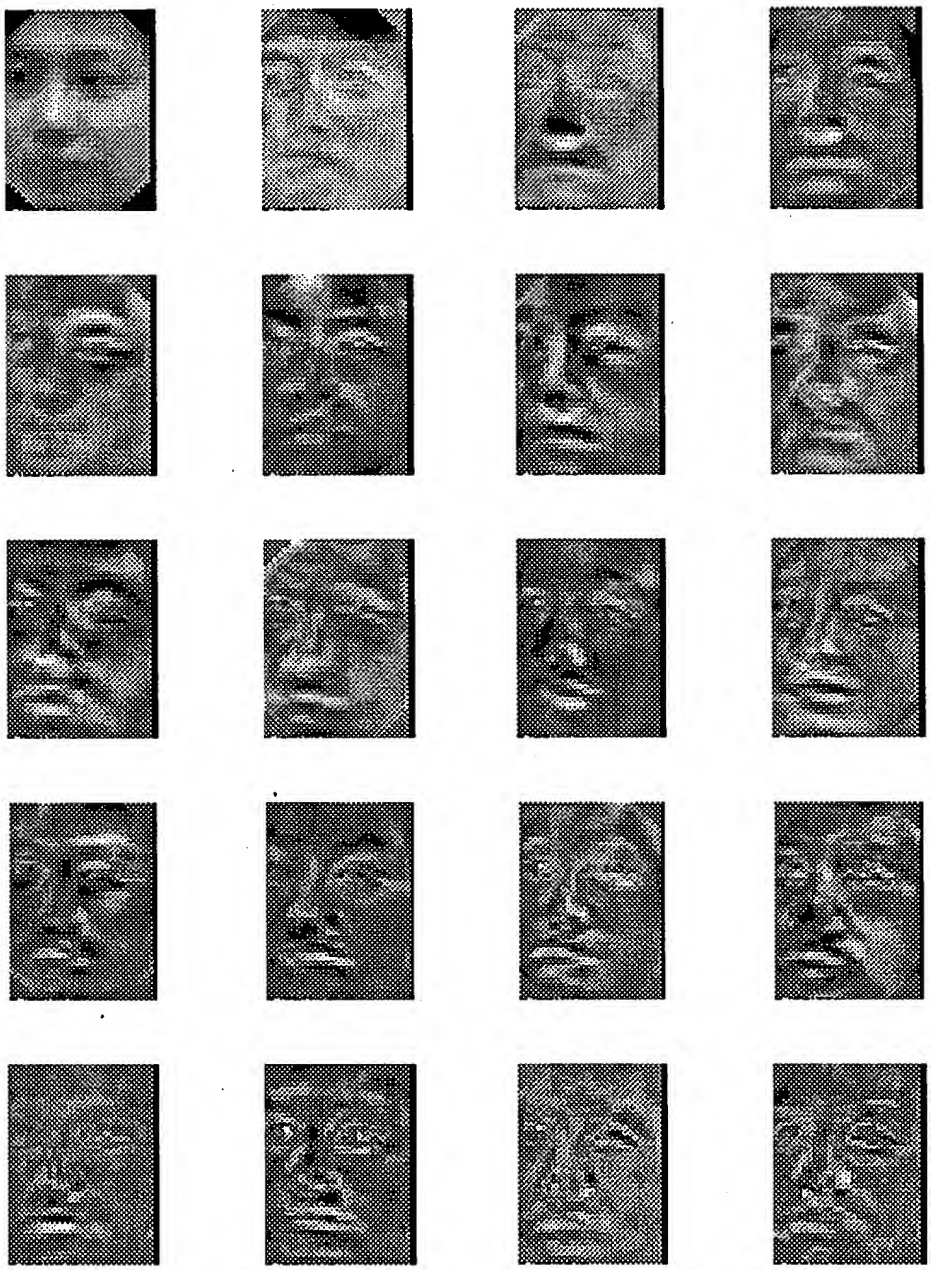
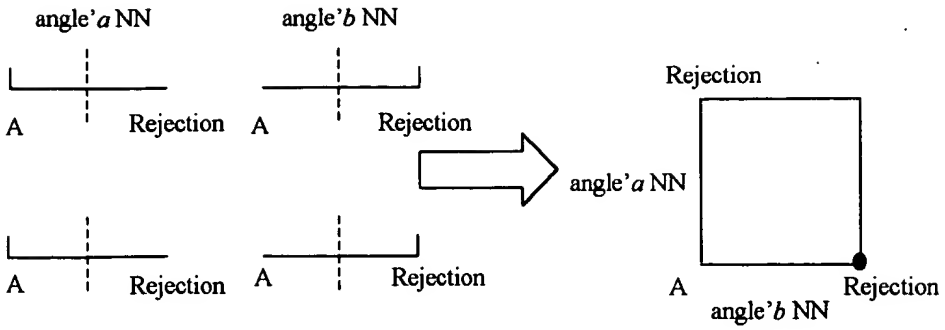
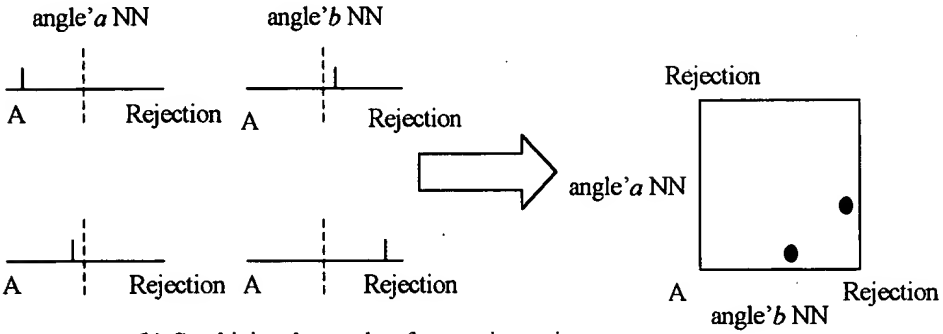


FIG. 12

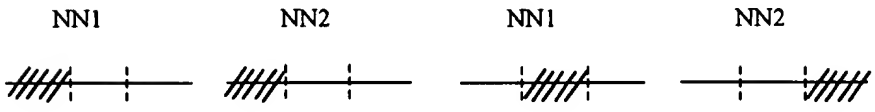



(a) Combining the results of classifiers




(b) Combining the results of regression estimators

FIG. 14




(a) person A's angle'*a* image fed

(b) person A's angle'*b* image fed

(c) person B's angle'*a* image fed

(d) person B's angle'*b* image fed

FIG. 15

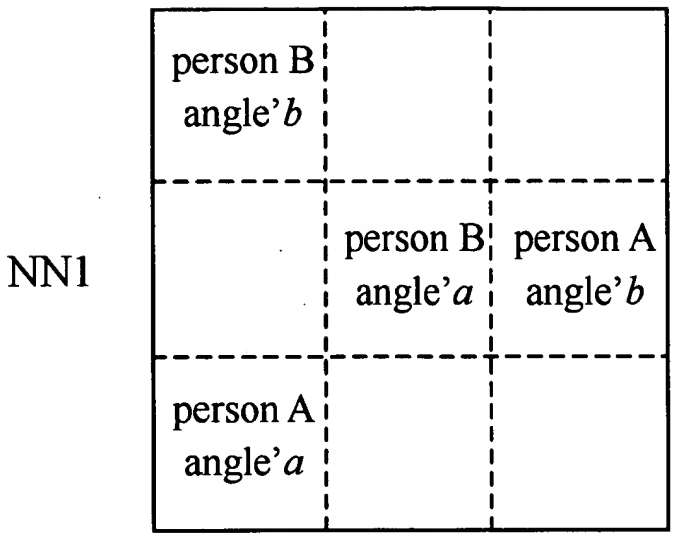

person B
angle'b
person B
angle'a
person A
angle'b
person A
angle'a
NN1
NN2

FIG. 16